# EECS C145B / BioE C165: Image Processing and Reconstruction Tomography: Spring 2003

## 1 Course details

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| Lectures: | 12:30 pm - 2:00 pm Tuesday and Thursday |
| Location: | 247 Cory Hall |
| Course control number: | 25539 |
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| Discussion section: | 11:00 am - 12:00 pm Friday |
| Location: | 299 Cory Hall |
| Course control number: | 25542 |
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| Scheduled office hours: | 2:15 pm-3:15 pm Thursdays |
| Location: | 462 Evans Hall |
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| Course website: | http://muti.lbl.gov/145b |

## 2 Course texts and recommended references

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| Required texts: | Digital Image Processing, 2nd Edition<br>Gonzalez & Woods, Prentice Hall (2002).<br>Book website: www.imageprocessingbook.com |
| | Course reader<br>Available from Copy Central on Hearst Ave<br>just west of Euclid. |

Recommended additional reference texts:

Discrete-time Signal Processing
Alan V. Oppenheim and Ronald W. Schafer
Prentice Hall (1989)

Fundamentals of Digital Image Processing
Anil K. Jain, Prentice Hall (1989).

Digital Image Processing
Kenneth R. Castleman, Prentice Hall (1996).

Digital Image Restoration
H.C. Andrews and B.R. Hunt
Prentice-Hall (1977)

Two-dimensional Imaging
Ronald N. Bracewell
Prentice Hall (1995)

## 3 Prerequisites

This course has no official prerequisites. Knowledge of basic linear systems, convolution and basic Fourier analysis is desirable.

## 4 Grading policy

Your grade will be determined as follows:

- 20% Written homework problems
- 25% Matlab programming exercises
- 15% Midterm: Thursday March 20, in class
- 40% Final

### Homework

Collaboration in groups of up to three people is encouraged. The individual responsible for writing up the completed assignment should alternate.

1. Please submit all homework as hardcopy.

2. Submit only one completed assignment per group.

3. List the names of all collaborators and reference texts used at the top of each completed assignment. The individual responsible for writing up the assignment should be identified.

4. If you cannot print out a complex image, place it on a web page and give a reference to the picture in the hardcopy. Do not e-mail large images to the instructor or TA.

5. Submit all source code used to solve a homework problem. Comment the code so that the logic behind your work is clear to the evaluator. If it's clear you know what you're doing, it's clear you deserve a good grade.

6. Label all graphs and axes. Use colorbars to show color scales where appropriate.

7. Organize material in a clear and logical way.

Assignments submitted late without prior arrangements or reasonable excuse will be penalized as follows:

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| 1 day | 5 % |
| 2 days | 10 % |
| additional days | 20 % per day |

## 5 Lecture and discussion schedule (subject to change)

### January 21

1. What is an image?

2. Digital images

3. Color images

4. Luminance and contrast

5. Examples of image formation and contrast mechanisms

6. What will be covered in this course?

7. Student background and interests questionnaire

**January 23**

1. Review of linear time/shift invariant systems
2. Review of discrete convolution in 1D
3. 1D convolution as a matrix operation
4. Convolution in 2D
5. 2D convolution as a matrix operation

**January 24 Discussion**

Convolution and Fourier analysis review.

**January 28**

1. The inverse problem of deconvolution (image restoration)
2. Motivation for studying the discrete Fourier transform in 2+D
3. Review of the 1D Fourier transform
4. The discrete Fourier transform (DFT)
5. Introduction to the 2D FT
6. The fast Fourier transform (self study)

**January 30**

Introduction to Matlab for image processing. Part I. (Joseph Yeh)

**January 31 Discussion**

Hands-on Matlab tutorial.

**February 4**

1. The 2D discrete Fourier transform (DFT).
2. Properties of the 2D DFT.
3. Implementation of the 2D DFT.
4. Introduction to Matlab for image processing. Part II.

**February 6**

1. Design of image filters in the frequency domain.
2. Examples of image filters in the space domain, including non-linear filters.

**February 7 Discussion**

1. Recap on the 2D DFT.
2. Work through an image filtering problem.

**February 11**

1. Image enhancement.
2. The image histogram.
3. Introduction to image restoration and the inverse problem.

**February 13**

1. Least-squares methods.
2. The pseudoinverse.
3. The singular value decomposition (SVD).
4. Geometric interpretation of range and nullspace.
5. SVD for image compression.

**February 14 Discussion**

SVD noise removal and image compression example.

**February 18**

1. Image restoration example.
2. Motivation for tomographic imaging.
3. Qualitative introduction to tomography. Locating a single source in space. Locating multiple sources.

**February 20**

1. Definition of tomography.
2. History of tomography.
3. Vector represenation of lines and line integrals.
4. Concept of projections.
5. Mathematical expression of projections.
6. The Radon transform of 2D distributions.

**February 21 Discussion**

1. Projecting and backprojecting using Matlab.
2. Reconstruction tomography in Matlab.
3. Radon transform and reconstruction example.
4. Properties of the Radon transform.
5. The Fourier projection slice theorem (PST).
6. Reconstruction using the PST.
7. The backprojection operator.
8. The kernel of the backprojection operator.

**February 25**

1. Filtered backprojection (FBP) and backprojection of filtered projections (BPFP).
2. Modification of the ramp filter.
3. Projection as a matrix operation.
4. Inverting the Radon transform using the pseudoinverse.
5. Algebraic reconstruction algorithm (ART).

**February 27**

x-ray computed tomography (CT) theory, instrumentation and applications.

**February 28 Discussion**

The Fourier projection slice theorem.

**March 4**

1. Emission tomography.
2. SPECT theory, instrumentation and applications.
3. Attenuation and scatter.

**March 6**

1. Positron emission tomography (PET).
2. Comparison of PET and SPECT.

**March 7 Discussion**

1. Quantitative analysis of sensitivity differences between PET and SPECT.

**March 11**

1. Frontiers of PET instrumentation.
2. Small animal PET.
3. Fundamental factors limiting PET.
4. Search for new scintillators.

**March 13**

Introduction to nuclear magnetic resonance (NMR) physics.

**March 14 Discussion**

Review for midterm.

**March 18**

1. Sources of contrast in NMR.
2. Magnetic resonance imaging (MRI) instrumentation.
3. Review for midterm.

**March 20**

Midterm.

**March 21**

No discussion.

**April 1**

1. Pulse sequences. Spin-echo.
2. Mathematical justification of phase encoding.

**April 3**

1. Projection MRI.
2. Functional MRI (fMRI).
3. Diffusion tensor imaging.

**April 4 Discussion**

Simulating spin-echo MRI data and reconstructing it.

**April 8**

1. Imaging frontiers and trends.
2. Molecular imaging.
3. Imaging gene expression.

**April 10**

Ultrasound imaging.

### April 11 Discussion

General discussion.

### April 15

1. Introduction to dynamic imaging.
2. Tracer kinetic models.

### April 17

1. Fitting compartmental models to image regions.
2. Statistics in imaging. Application to laser Doppler skin response images.

### April 18 Discussion

1. Statistical sampling.
2. Student's t-test.

### April 22

1. Correlation.
2. Importance of study design.

### April 24

Biostatistics in imaging: study examples.

### April 25 Discussion

Work through biostatistics examples.

### April 29

1. Image coding.
2. Image compression.

### May 1

1. Optical flow and video compression.
2. Orientation maps.

### May 6

Image segmentation and classification I.

### May 8

1. Image segmentation and classification II.
2. Hand-out practise final.

### May 9 Discussion

Help with exam preparation.

### May 13

Review practise final.